Two-stage stochastic optimization of district heating and cooling system investment and dispatch with high shares of geothermal sources and aquifer thermal energy storage

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Overview

The primary goal of this work is to investigate the robust cost-effective investment and dispatch decision of district heating and cooling systems under a long-term planning horizon. Particularly, this includes the integration of high shares of geothermal sources and aquifer thermal energy storage (ATES) in order to decarbonize not only the fueling energy mix but also to improve the energy generation and demand matching in the systems.

Methods

A two-stage stochastic optimization model is developed, whereby the first stage is the investment decision into energy technologies and storage. This decision considers uncertainties that are reflected in different scenarios but are ultimately scenario independent. The second stage encompasses the energy technology and storage dispatch and is for each scenario differently. A stochastic optimization approach is used since existing literature in the field of modelling ATES highlights the impact of various uncertainties on its economic viability ***[1]***. Accordingly, the main input parameters subject to uncertainties are electricity and gas prices and the heating and cooling demand. The demand uncertainties are driven by the extent of additionally supplied demand (e.g., the connection of new customers to the networks) and the magnitude and speed of building efficiency measures (e.g., passive building renovation). The objective function is to minimize the net present value of the district heating and cooling system operator by supplying all the heating and cooling demand. The key result is the optimal investment decision into energy technologies, represented by the value of installed capacity per energy technology and storage $\boldsymbol{Q_{t,y}^{ins}}$ in the optimal case:

$$Q_{t,y}^{*} = \underset{Q_{t,y}^{ins}}{\operatorname{argmin}}\, z$$

Thereby, the index t indicates the energy technology and storage. The index y corresponds to the year within the planning horizon. Total cost z is the sum of costs for investment, operation and maintenance for the planning period. For readability, the following derived parameters are introduced, whose definitions are given below: c_t^{inv} (net present value of the total investment costs) and $c_{t,w}^{dis}$ (net present value of total dispatch costs). The index w indicates the scenario and Ω_w its probability.

$$z = \sum_{t \in T} \left(c_t^{inv} + \sum_{w \in W} \Omega_w * c_{t,w}^{dis} \right)$$

We demonstrate the developed methodology using a real test bed in Vienna, Austria. Especially, this area is choosen as a distinctive district heating and cooling systems exists (which currently mainly is supplied by fossil-fuel based energy technologies, such as combined heat and power units), and potentials for both geothermal sources and ATES are recently discovered there.

Results & Conclusions

Expected results should demonstrate particularly the role of geothermal sources and ATES in the decarbonization of existing district heating and cooling systems. This includes, among others, to demonstrate how the utilization of ATES provide flexibilities to efficiently use excess heat sources (e.g., industrial excess heat) and sustainable heat and cold energy technologies with constant generation, such as geothermal sources and waste incineration plants.

References

[1] T. Yang, W. Liu, G. J. Kramer und Q. Sun, „Seasonal thermal energy storage: A techno-economic literature review," *Renewable and Sustainable Energy Reviews,* 2021. Doi: https://doi.org/10.1016/j.rser.2021.110732.